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Introduction

This Addendum extends the conclusions and recommendations provided in the Interconnection System Impact Study (“ISIS”) Report dated February 25th, 2005 for MISO project #G376, MISO Queue #37935-03.

This Addendum is required due to the Generator changing from the Vestas V80 2.0 MW machines with AG04 low voltage ride-through in the original Facility Study to a proposed configuration of GE 1.5 MW machines. This Addendum reviews the stability impact of the new wind turbines for only a subset of the faults analyzed in the Facility Study determined to be the worst-case scenarios for the G376 interconnection.

The ISIS found single contingency analysis required the lowest permissible leading power factor (i.e. absorbing MVar) for G376 to be 0.99 at the point of interconnection (“POI”) with the ATC transmission system. All stability analysis was performed with the 0.99 power factor.

The ISIS required Operation Restrictions on the wind farm due to prior outage stability conditions. With the customer provided low voltage ride through (“LVRT”) the performance of the proposed GE induction machines is better than the original Vestas units. The Stability Operation Restrictions identified in the ISIS will no longer be required. Table A.3 shows the changes in system and machine performance for the studied faults. The wind farm will require the proposed LVRT shown in figure E.1.

Therefore, based on the model supplied by the Generator for this restudy, the proposed configuration change is acceptable.

Appendix A: Updated Stability Analysis

**Table A.3 – Stability Analysis Results of Prior Outage Contingencies
For the Expected 2005 System After the Addition of G376 Generation**

Item	Faulted Facilities ^{2,3}	Prior Outage	MECT ⁴	With G376 Including Competes	
				ISIS CCT ⁴	Addendum CCT ⁴
1	GSS- RDR 138 kV	G376 – NFL 138 kV	5	<5.0	≥6.0
2	GSS- NOR 138 kV	G376 – NFL 138 kV	5	<5.0	≥6.0
3	G376 – NFL 138 kV	GSS- RDR 138 kV	5	<5.0	≥6.0
4	G376 – NFL 138 kV	GSS- NOR 138 kV	5	<5.0	≥6.0

Notes:

1. All analysis performed with G376 operating at 0.99 leading (absorbing) power factor.
2. Table abbreviations: GSS – Green Lake Substation, RDR – Roeder, NFL – N. Fond du Lac, NOR – N. Randolph.
3. The fault is applied at the first named terminal of the faulted element unless otherwise noted. All faults modeled were 3- phase faults.
4. Calculated CCT = Critical Clearing Time (cycles). MECT = Actual Maximum Expected Clearing Time (cycles). Red cell indicates actual equipment clearing times that times that are inadequate.

Appendix D: Updated Summary of Operation Restrictions

**Table D.1 – Identified Operation Restrictions on
the G376 Generation Under Prior Outage Scenarios**

Prior Outage ¹	G376 Max Allowable Output (MW)	Worst Next Contingency	Limiting Element ²	MVA Rating	Reason	Season
N. Fond du Lac – Metomen 138 kV	0	Green Lake – G376 138kV	Metomen – Rosendale 69 kV	36	Thermal	Summer
Green Lake – G376 138 kV	0	N. Fond du Lac – Metomen 138kV	Metomen – Rosendale 69 kV	36	Thermal	Summer

**Table D.2 – Outage Statistics for Contingent/Prior
Outage Lines Identified Under Prior Outage Scenarios**

Contingent Element	Line Length (miles)	Total # of Outages 1/1/2000 – 1/1/2005	Average Duration (minutes)	Outages per 100 mile-years
X-3: North Fond du Lac – Metomen 138 kV ¹	42.53	1	0.08	0.55
X-4: Green Lake – North Fond du Lac 138 kV	29.30	4	2.83	2.73

Notes:

1. Line length for North Fond du Lac – Metomen 138 kV is measured from North Fond du Lac to North Randolph 138 kV, the next breakered substation.

Appendix E: Updated Fault Ride-Through Characteristics For G376 GE Wind Turbines

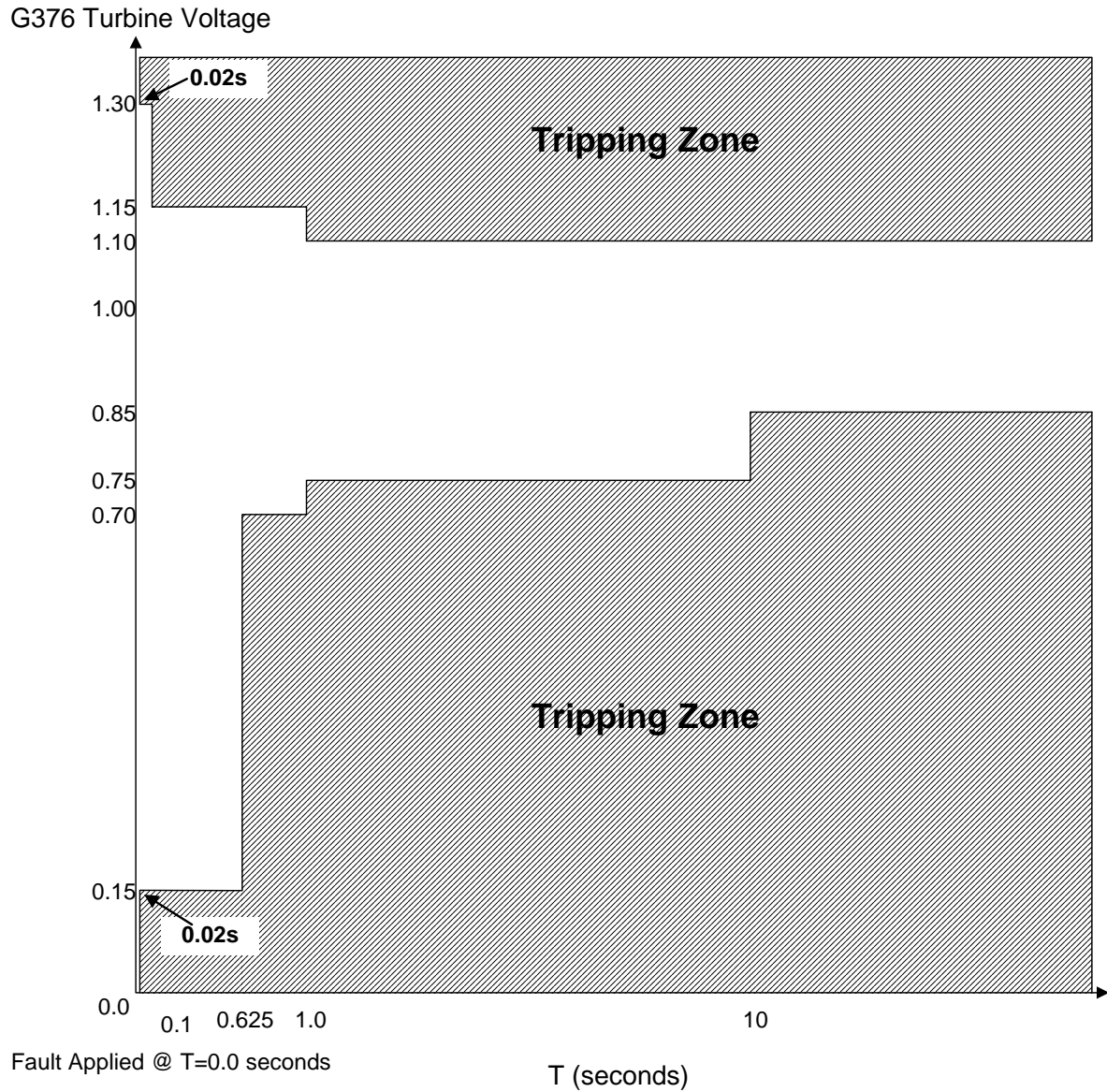


Figure E.1 – Customer Provided Fault Ride-Through Characteristics Related to Voltage Tripping of G376 GE Wind Turbines



Interconnection System Impact Study Report

**160 MW Wind Generation in
Green Lake/Fond du Lac County, Wisconsin
MISO # G376 (#37935-03)**

Prepared for the Midwest ISO

March 1st, 2005

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1. Summary

This report contains the Interconnection System Impact Study (“ISIS”) for the Generation Interconnection Request MISO project #G376, MISO Queue #37935-03. The purpose of this study is to identify system upgrades that will eliminate all thermal and stability impacts found in the Interconnection Evaluation Study (“IES”) dated October 15, 2004. The requested in-service date for this project is June 1, 2006.

The proposed wind farm will connect to the 138 kV line between Green Lake and North Fond du Lac substations (line X-4). Figure 1.1 shows the system one-line diagram before G376 has been added. Alternative interconnections to the adjacent 138 kV line between Metomen and North Randolph (line X-3) or to both circuits (line X-3 and line X-4) are no longer under consideration.

Required G376 Interconnection Equipment

The proposed G376 wind farm will have a single collection bus at a voltage level of 34.5 kV. A single 138/34.5 kV transformer and breaker will connect the wind farm collection bus to a new substation to be located adjacent to the X-4 line in a two breaker straight bus configuration, as shown in the Figure 1.2. The Transmission Owner provided equipment, is as shown in Tables 1.2 Item #1 and Table 1.3, and the associated interconnection work is estimated to cost \$2,600,000.

The Generator is responsible for all equipment with in the Generator owned substation, including the GSU high side circuit breaker, GSU transformer, all 34.5 kV equipment and sundry apparatus.

Power Flow Impact due to G376

The IES identified steady state voltage violations due to G376. To maintain acceptable steady state voltage performance, the wind farm power factor at POI must be no lower than 0.99 p.u. leading (absorbing), see Table C.4. The identified thermal violations due to the G376 generation addition under N-1 and N-2 conditions are summarized in Tables C.1 to C.4 in Appendix C.

The voltage violations listed in Table C.3 (winter 2006/2007 base case) and Table C.4 (summer 2006 base case) are mitigated by a combination of the installation of capacitors previously identified by ATC, one required for G368 and by requiring G376 to operate at no less than 0.99 p.u. leading power factor, as previously noted. The identified capacitor bank projects are at the G368 138 kV bus (G368 study) and at Hartford and Burlington 138 kV busses (ATC Ten Year Assessment). These facilities are expected to be in service before the G376 in-service date.

The multiple changes to the power flow impact results were due to an increase in the line rating of the line X-4 Green Lake Substation – North Fond du Lac 138 kV, interconnection request G371 dropping out of the queue, a reconductor of line 13878 Columbia – North Madison 138 kV, and a review of all line ratings that were shown to be limiting in the IES.

Stability Impact due to G376

Results of the stability analysis are summarized in Tables A.1 through A.3 in Appendix A. Stability analysis identified that the G376 wind farm trips off line for prior-outage contingencies where the wind farm has only one outlet, with high impedance, to the transmission system post contingency. The wind farm tripping off line under prior outage contingencies is remedied by operating restrictions on the MW output of the wind farm.

System Upgrades

Existing System Before G376

Stability Related

None.

Breaker Duty Related

None.

Required Upgrades After G376

Power Flow Related

The wind farm must maintain a power factor of at least 0.99 leading (Absorbing VAR's).

Stability Related

None.

Breaker Duty Related

None.

Proposed Upgrades After G376 - Thermal and Steady-State Voltage Related

Replacement of terminal equipment at the Wautoma substation is required to meet N-1 criteria. After this upgrade, only N-2 violations remain and no upgrades have been proposed at this time. However, operating restrictions are proposed for G376 for these N-2 conditions.

Operation Restrictions

The identified operation restrictions on the G376 generation due to thermal and stability violations under prior outage conditions are summarized in Table D.1 in Appendix D. Table D.2 summarizes the past five years of outage statistics for all contingent lines identified in the operation restrictions.

Table 1.1 –Upgrades Required for the Existing System Prior to the Interconnection of G376

Locations	Facilities
	NONE

Table 1.2 – Required Interconnection Equipment for G376

Locations	Facilities	Cost Estimate
G376	Item #1 – Construct bus work from the new ATC substation network bus path (as described in Table 1.3 Item #1) to the adjacent Generator owned substation. This item includes the customer supplied switch at the POI, dead-end structure supporting the generator leads exiting the ATC substation, bus work, and etc. all of which are within the new ATC switchyard fence.	\$211,000
G376	Item #2 - All apparatus with in the Generator Owned substation including the GSU high side circuit breaker, GSU transformer and all 34.5kV apparatus. The customer is required to provide this equipment and the cost are unknown at this time.	N/A

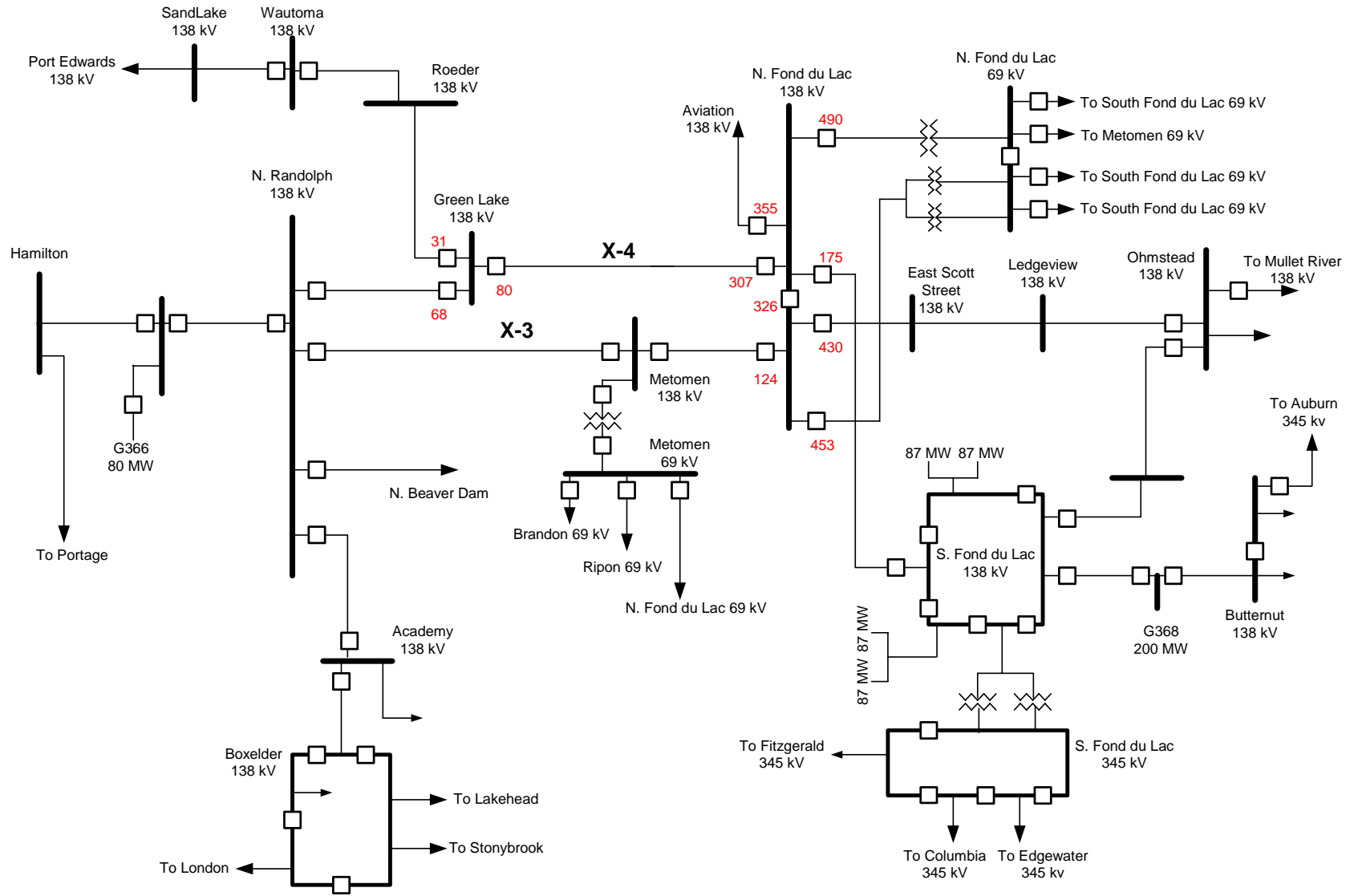
Table 1.3 – Required System Upgrades due to the Addition of G376

Locations	Facilities	Cost Estimate
G376	Item #1- Work associated with the new ATC substation built adjacent to line X-4 including, but not limited to, the line tap of X-4, two new 138 kV circuit breakers and associated disconnects, control building, bus work and sundry apparatus within the ATC substation fence but excluding Item #1 from Table 1.1.	\$2.29M
Green Lake	Item #2 - Relaying Upgrades/Setting Changes only.	\$50 k
N. Fond du Lac	Item #3 - Relaying Upgrades/Setting Changes	\$50 k

Table 1.4 – Proposed Upgrades due to Thermal Overloads 160 MW Generation Delivery from G376 to ComEd(75%) and NSP(25%) Control Area

Locations	Facilities	Cost Estimate
Wautoma	Item #1 – Replace current transformers on 69 kV breaker.	\$125,000
Wautoma	Item #2 – Upgrade relaying for the Wautoma – Green Lake 138 kV line.	\$50,000
	Total	\$175,000

Figure 1.1 – One Line Diagram of the Existing System Before the Addition of G376



2. Criteria, Methodology and Assumptions

2.1 Study Criteria

All relevant MISO-adopted NERC Reliability Criteria and the ATC contingency criteria are to be met for both the stability analysis and the thermal analysis. Details of the stability and thermal analysis criteria applied in this study can be found in Appendix F.

2.2 Study Methodology

The results of this study are subject to change. The results of the Study are based on data provided by the Generator and other ATC system information that was available at the time the study was performed, and the Thermal Study does not guarantee a position in the Transmission Service Request Queue. If there are any significant changes in the generator and controls data, in earlier queue Generator Interconnection Requests, in related Transmission Service Requests, or ATC transmission system development plans, then the results of this study may also change significantly. Therefore, this request is subject to restudy. The Generator is responsible for communicating any significant generation facility data changes in a timely fashion to ATC prior to commercial operation.

2.2.1 Competing Generation Requests

ATC determined in its sole judgment that two GIRs with earlier queue positions might impact the G376 study results. G366 and G368 are considered competing requests for the interconnection of this generator. G368 is a proposed 200 MW wind farm located between South Fond du Lac and Butternut 138 kV substations as shown in Figure 1.2. G366 is an 80 MW wind farm located between North Randolph and Hamilton 138 kV substations as shown in Figure 1.2. G371, a proposed 99 MW wind farm was to be interconnected at the same substation as G366 but has dropped from the queue since the G376 EIS. The thermal and stability results were reviewed to determine the impact of G376 without G371 interconnected to the transmission system.

Public information related to GIR queue can be found via the MISO web site at <http://oasis.midwestiso.org/documents/ATC/queue.html>

2.2.2 Before and After Comparison Approach Employed in Stability Analysis

In the stability analysis performed for this study, to identify what impacts should be attributed to the addition of G376 interconnection; two system conditions were examined - “Before” the addition of G376 and “After” the addition of G376. Any violations of the stability study criteria identified in the “Before” state are defined to be existing system violations. Any new violations identified in the “After” state or violations identified in both “Before” and “After” states and are worse in the “After” state are to be attributed to the addition of G376. Only those existing system violations that are made worse by the G376 wind farm are deemed relevant to the G376 interconnection request and are documented in this report. Any other identified existing system

violations that are not made worse by the G376 wind farms are deemed unrelated to the G376 interconnection requests and are documented elsewhere as part of the internal ATC planning projects.

The stability analysis was performed using the Dynamics Simulation and Power Flow modules of the Power System Simulation/Engineering-28 (PSS/E, Version 28) program from Power Technologies, Inc (PTI). This program is accepted industry-wide for dynamic stability analysis.

2.2.3 Linear Transfer Analysis and A.C. Load Flow Analysis Methods Employed in Thermal Overload and Steady-State Voltage Evaluations

For thermal overload and steady-state voltage evaluation under normal, N-1 and special ATC multiple contingency conditions, AC Contingency Calculation (ACCC) method was used. For thermal overload evaluation under N-2 conditions, Linear Transfer Analysis method was used with adjusted MW ratings to account for reactive power flows.

The Linear Transfer analysis was performed using the Linear Transfer Analysis modules of the Managing and Utilizing System Transmission-5.0 (MUST, Version 5.0) program from Power Technologies, Inc (PTI). ACCC was performed using the Power Flow module of the Power System Simulation/Engineering-28 (PSS/E, Version 28) program from Power Technologies, Inc (PTI). These programs are accepted industry-wide for power flow analysis.

2.2.4 Base Cases

For the power flow analysis, two system conditions were evaluated, which represent expected summer 2006 and winter 2006/07 conditions.

In the thermal overload analysis of this study, MISO (Midwest Independent System Operator) monthly cases, January 2005 and July 2004 were used. The MISO monthly cases are accessible through MISO Extranet. The January 2005 and July 2004 base cases were utilized to develop Summer 2006 and Winter 2006/2007 base cases. The Winter 2006/2007 base case was developed based on the MISO January 2005 model created from the 2001 Series NERC/MMWG. Loads were scaled to the expected Winter 2006/07 peak levels. All ATC projects expected to be completed and in-service by June 2006 were also added including G366 and G368. The Summer 2006 base case was developed based on a MISO July 2004 model created from the 2002 Series NERC/MMWG. Similar to the Winter case, loads were scaled to the expected Summer 2006 peak levels. All ATC projects expected to be completed and in-service by June 2006 projects were also added. G376 full plant output (160 MW) was delivered to the NSP (25%) and ComEd (75%) control areas. Loads in the control area were increased accordingly for the increased ATC export level.

In the stability analysis of this study, a 2005 50% summer peak load case was used. This base case was developed based on a NERC 2002 series MMWG (Multi-Regional Modeling Working Group) 2004 50% summer peak load case. The 2004 50% peak load case was modified by scaling load up by 3% and economically dispatching existing system generation to model the 2005 time period. Planned 138 kV capacitor additions at Burlington and Hartford, along with an

accelerated G368 138 kV capacitor, were added to the dynamics model based on steady state voltage analysis results. In addition, the base case was further modified to include G366 and G368 wind generation dynamic models.

2.3 Assumptions

2.3.1 Generation Facility Modeling

The G376 wind farm is modeled by a lumped representation in this study. It is modeled as a generator for the power flow analysis and represented by a user-written model in the dynamic simulations. This user-written model includes dynamic representations of the wind machines and voltage tripping relays. The wind turbine fault ride-through capability is included in the modeling as shown in Appendix E. The latest wind turbine user written model was used in the ISIS for evaluation of G376.

The G376 generation was modeled at 0.99 lead power factor (absorbing MVAR) at the Point Of Interconnection (POI) for the power flow analysis and stability analysis.

3. Analysis Results

3.1 Stability Analysis Results

The stability criteria used in this study requires that all machines modeled in the system must remain stable after a three-phase fault is cleared from any transmission element under the following conditions:

- 1) Fault cleared in primary time with an otherwise intact system
- 2) Fault cleared in primary clearing time with a pre-existing outage of any other transmission element.

The stability criteria also require that all machines remain stable for a fault cleared in delayed clearing time (i.e. breaker failure conditions) with an otherwise intact system. Wind turbines are exempt from this criterion, but must not aggravate system performance.

Results of the stability analysis are summarized in Tables A.1 through A.3 in Appendix A.

3.1.1 Results of Primary Fault Contingencies

The primary contingency results with normal clearing are summarized in Table A.1 in Appendix A. Stability analysis did not identify violations for any primary contingencies with normal clearing when the G376 generation is at its full capacity of 160 MW. No damping violations were found for any of these contingencies.

3.1.2 Results of Breaker Failure Contingencies

The breaker failure contingency results are summarized in Table A.2 in Appendix A. Numerous contingencies studied caused G376 to trip off line. In all of the cases evaluated, the addition of G376 did not aggravate system performance. No damping violations were found for any of the breaker failure contingencies studied.

3.1.3 Results of Prior Outage Contingencies

The prior outage, primary clearing fault study results are summarized in Table A.3 in Appendix A. The prior outage of G376 outlet to N. Fond du Lac followed by the primary clearing of Green Lake to either Roeder or to N. Randolph results in violation of ATC stability criteria (G376 either trips due to over-voltage or fails to achieve an acceptable steady state operation.) This appears to be due to a weak path from Green Lake to either Roeder or to N. Randolph that is unable to adequately handle the full output of G376 on recovery from fault. Similarly, the prior outage of either Green Lake to Roeder and or Green Lake to N. Randolph result in violation of ATC stability criteria when followed by primary clearing of G376 outlet to N. Fond du Lac. Stability studies show that restricting G376 to 80 MW will mitigate stability problems for these three prior outages (as given in Appendix D). These findings are consistent with the IES results. In the ISIS, the customer and ATC sought to resolve potential modeling issues associated with the observation high voltage response. However, these modeling issues were not resolved and the operating restrictions remain. The operating restrictions will be reviewed if the customer supplies an updated model.

3.2 Short-Circuit Analysis Results

Short-circuit analysis was not performed due to the fact that the induction generators typically contribute significant short-circuit current only within the first 1 ~ 1.5 cycles after a fault. No system upgrades due to breaker duty are required prior to the interconnection of G376.

The maximum and minimum short-circuit duties at the G376 Point of Interconnection (POI) and the Thevenin equivalent impedances at the G376 POI are provided in Tables B.1 through B.3 in Appendix B.

3.3 Power Flow Analysis Results

Table C.1 and Table C.2 in Appendix C list the thermal overloads caused by G376 or in which G376 contributes to the loading problem for the intact system and also for the system with single (N-1) and double (N-2) contingency conditions. The only overload with single contingency condition is the Wautoma 138/69kV transformer. This overload will be resolved with new relay settings and CT modifications. Restrictions will be used to mitigate the overloaded element for the system with double (N-2) contingency conditions. Appendix D summarizes the operating restrictions based on the overloads listed in Appendix C.

The IES identified under-voltage violations for Winter 2006/2007 and Summer 2006, as shown in Tables C.3 and C.4. The voltage violations are mitigated by a combination of the installation of capacitors previously identified by ATC, one required for G368 and by requiring G376 to operate at no less than 0.99 p.u. leading power factor, as previously noted. The identified

capacitor bank projects are at the G368 138 kV bus (G368 study) and at Hartford and Burlington 138 kV substations (ATC Ten Year Assessment). These facilities are expected to be in service before the G376 in-service date.

Appendix A

Stability Analysis Results

Notes:

1. All analysis performed with G376 operating at 0.99 leading (absorbing) power factor.
2. Table abbreviations: NOR – North Randolph, GSS – Green Lake, NFL – North Fond du Lac, AVI – Aviation, MET – Metomen, SFL – South Fond du Lac, EST – Ohmstead, RDR - Roeder
3. The fault is applied at the first named terminal of the faulted element unless otherwise noted. All faults modeled were 3-phase faults.
4. Calculated CCT = Critical Clearing Time (cycles). MECT = Actual Maximum Expected Clearing Time (cycles). Red cell indicates actual equipment clearing times that times that are inadequate.
5. Voltage Recovery column indicates if voltage recovery after fault is cleared was acceptable (system bus voltage magnitudes must recover to be at least 70% of the nominal system voltages immediately after fault removal and 80% of the nominal system voltages in 0.5 second after fault removal.)
6. G376 trips when the terminal voltage is less than 0.5 pu for more than 0.2 seconds (see Appendix E).
7. N/A – Run not applicable.

Table A.1 – Stability Analysis Results of Primary Fault Contingencies Utilizing 2005 System After the Addition of G376 Generation¹

Item	Faulted Facilities ^{2,3}	MECT ⁴	Calculated CCT ⁴	Voltage Recovery ⁵	Comments
1	G376 – GSS 138 kV	5	> 6	acceptable	None
2	G376 – NFL 138 kV	5	> 6	acceptable	None
3	NFL – G376 138 kV	5	> 6	acceptable	None
4	NFL – AVI 138 kV	5	> 6	acceptable	None
5	NFL – MET 138 kV	5	> 6	acceptable	None
6	NFL – SFL 138 kV	5	> 6	acceptable	None
7	NFL – EST 138 kV	5	> 6	acceptable	None
8	NFL 138/69 kV	5	> 6	acceptable	None
9	GSS- G376 138 kV	5	> 6	acceptable	None
10	GSS- RDR 138 kV	5	> 6	acceptable	None
11	GSS- NOR 138 kV	5	> 6	acceptable	None

Table A.2 – Stability Analysis Results of Breaker Failure Contingencies utilizing 2005 System After the Addition of G376 Generation¹

Item	Faulted Facilities	Failed Ckt. Brkr	Element(s) Cleared In Breaker Failure	MECT	Calculated CCT ⁴	Voltage Recovery ⁵	Transient Problems
1	NFL – G376 138 kV	307	490, 355, 175, 326	18	≥19 ⁵	acceptable	None
2	NFL – AVI 138 kV	355	490, 307, 175, 326	18	≥19 ⁵	acceptable	G376 tripped 17 cycles after fault ⁷
3	NFL – MET 138 kV	124	326, 430, 453	18	≥19 ⁵	acceptable	G376 tripped 17 cycles after fault ⁷
4	NFL – SFL 138 kV	175	490, 355, 307, 326	18	≥19 ⁵	acceptable	G376 tripped 17 cycles after fault ⁷
5	NFL – EST 138 kV	430	326, 124, 453	18	≥19 ⁵	acceptable	G376 tripped 17 cycles after fault ⁷
6	NFL 138/69 kV (# 1)	453	124, 326, 430	19	≥20 ⁵	acceptable	G376 tripped 17 cycles after fault ⁷
7	NFL 138/69 kV (# 2)	490	175, 307, 326, 355	19	≥20 ⁵	acceptable	G376 tripped 17 cycles after fault ⁷
8	GSS- G376 138 kV	80	68, 31	18	≥19 ⁵	acceptable	None
9	GSS- RDR 138 kV	31	68, 80	18	≥19 ⁵	acceptable	G376 tripped 17 cycles after fault ⁷
10	GSS- NOR 138 kV	68	31 , 80	18	≥19 ⁵	acceptable	G376 tripped 17 cycles after fault ⁷

**Table A.3 – Stability Analysis Results of Prior Outage Contingencies
Utilizing 2005 System After the Addition of G376 Generation¹**

Prior Outage	Item	Faulted Facilities	MECT	Calculated CCT ⁴	Voltage Recovery ⁵	Comments
G376 – NFL 138 kV	1a	G376 – NFL 138 kV	N/a			
	1b	G376 – GSS 138 kV	5	-	-	G376 trips (no outlet remaining)
	1c	NFL – AVI 138 kV	5	> 6	acceptable	None
	1d	NFL – MET 138 kV	5	> 6	acceptable	None
	1e	NFL – SFL 138 kV	5	> 6	acceptable	None
	1f	NFL – EST 138 kV	5	> 6	acceptable	None
	1g	NFL 138/69 kV (# 1)	5	> 6	acceptable	None
	1h	GSS- RDR 138 kV	5	< 5	Not acceptable	Nearby 138 kV voltage contains higher frequency components
	1i	GSS- NOR 138 kV	5	< 5	Not acceptable	G376 trips due to over-voltage
G376 – GSS 138 kV	2a	G376 – NFL 138 kV	5	-	-	G376 trips (no outlet remaining)
	2b	G376 – GSS 138 kV	N/a			
	2c	NFL – AVI 138 kV	5	> 6	acceptable	None
	2d	NFL – MET 138 kV	5	> 6	acceptable	None
	2e	NFL – SFL 138 kV	5	> 6	acceptable	None
	2f	NFL – EST 138 kV	5	> 6	acceptable	None
	2g	NFL 138/69 kV (# 1)	5	> 6	acceptable	None
	2h	GSS- RDR 138 kV	5	> 6	acceptable	None
	2i	GSS- NOR 138 kV	5	> 6	acceptable	None
NFL – AVI 138 kV	3a	G376 – NFL 138 kV	5	> 6	acceptable	None
	3b	G376 – GSS 138 kV	5	> 6	acceptable	None
	3c	NFL – AVI 138 kV	N/a			
	3d	NFL – MET 138 kV	5	> 6	acceptable	None
	3e	NFL – SFL 138 kV	5	> 6	acceptable	None
	3f	NFL – EST 138 kV	5	> 6	acceptable	None
	3g	NFL 138/69 kV (# 1)	5	> 6	acceptable	None
	3h	GSS- RDR 138 kV	5	> 6	acceptable	None
	3i	GSS- NOR 138 kV	5	> 6	acceptable	None
NFL – MET 138 kV	4a	G376 – NFL 138 kV	5	> 6	acceptable	None
	4b	G376 – GSS 138 kV	5	> 6	acceptable	None
	4c	NFL – AVI 138 kV	5	> 6	acceptable	None
	4d	NFL – MET 138 kV	N/a			
	4e	NFL – SFL 138 kV	5	> 6	acceptable	None
	4f	NFL – EST 138 kV	5	> 6	acceptable	None
	4g	NFL 138/69 kV (# 1)	5	> 6	acceptable	None
	4h	GSS- RDR 138 kV	5	> 6	acceptable	None
	4i	GSS- NOR 138 kV	5	> 6	acceptable	None
NFL – SFL 138 kV	5a	G376 – NFL 138 kV	5	> 6	acceptable	None
	5b	G376 – GSS 138 kV	5	> 6	acceptable	None
	5c	NFL – AVI 138 kV	5	> 6	acceptable	None
	5d	NFL – MET 138 kV	5	> 6	acceptable	None
	5e	NFL – SFL 138 kV	N/a			
	5f	NFL – EST 138 kV	5	> 6	acceptable	None
	5g	NFL 138/69 kV (# 1)	5	> 6	acceptable	None
	5h	GSS- RDR 138 kV	5	> 6	acceptable	None
	5i	GSS- NOR 138 kV	5	> 6	acceptable	None

Table A.3 Cont. – Stability Analysis Results of Prior Outage Contingencies Utilizing 2005 System After the Addition of G376 Generation¹

Prior Outage	Item	Faulted Facilities	MECT	Calculated CCT	Voltage Recovery	Comments
NFL – EST 138 kV	6a	G376 – NFL 138 kV	5	> 6	acceptable	None
	6b	G376 – GSS 138 kV	5	> 6	acceptable	None
	6c	NFL – AVI 138 kV	5	> 6	acceptable	None
	6d	NFL – MET 138 kV	5	> 6	acceptable	None
	6e	NFL – SFL 138 kV	5	> 6	acceptable	None
	6f	NFL – EST 138 kV	N/a			
	6g	NFL 138/69 kV (# 1)	5	> 6	acceptable	None
	6h	GSS- RDR 138 kV	5	> 6	acceptable	None
	6i	GSS- NOR 138 kV	5	> 6	acceptable	None
NFL 138/69 kV # 1	7a	G376 – NFL 138 kV	5	> 6	acceptable	None
	7b	G376 – GSS 138 kV	5	> 6	acceptable	None
	7c	NFL – AVI 138 kV	5	> 6	acceptable	None
	7d	NFL – MET 138 kV	5	> 6	acceptable	None
	7e	NFL – SFL 138 kV	5	> 6	acceptable	None
	7f	NFL – EST 138 kV	5	> 6	acceptable	None
	7g	NFL 138/69 kV (# 1)	N/a			
	7h	GSS- RDR 138 kV	5	> 6	acceptable	None
	7i	GSS- NOR 138 kV	5	> 6	acceptable	None
GSS- RDR 138 kV	8a	G376 – NFL 138 kV	5	< 5	Not acceptable	Nearby 138 kV voltage contains higher frequency components
	8b	G376 – GSS 138 kV	5	> 6	acceptable	None
	8c	NFL – AVI 138 kV	5	> 6	acceptable	None
	8d	NFL – MET 138 kV	5	> 6	acceptable	None
	8e	NFL – SFL 138 kV	5	> 6	acceptable	None
	8f	NFL – EST 138 kV	5	> 6	acceptable	None
	8g	NFL 138/69 kV (# 1)	5	> 6	acceptable	None
	8h	GSS- RDR 138 kV	N/a			
	8i	GSS- NOR 138 kV	5	> 6	acceptable	None
GSS- NOR 138 kV	9a	G376 – NFL 138 kV	5	< 5	Not acceptable	G376 trips due to over-voltage
	9b	G376 – GSS 138 kV	5	> 6	acceptable	None
	9c	NFL – AVI 138 kV	5	> 6	acceptable	None
	9d	NFL – MET 138 kV	5	> 6	acceptable	None
	9e	NFL – SFL 138 kV	5	> 6	acceptable	None
	9f	NFL – EST 138 kV	5	> 6	acceptable	None
	9g	NFL 138/69 kV (# 1)	5	> 6	acceptable	None
	9h	GSS- RDR 138 kV	5	> 6	acceptable	None
	9i	GSS- NOR 138 kV	N/a			

Appendix B

Short Circuit Analysis

Table B.1 – Maximum and minimum fault duties at the G376 point of interconnection without the contribution from G376.

Maximum Fault Duty		Minimum Fault Duty	
Single-phase	Three-Phase	Single-phase	Three-Phase
4900 Amps	6900 Amps	2800 Amps	3670 Amps

Note: Minimum fault duty was calculated with the G376 - North Fond du Lac 138 kV line out of service.

Table B.2 – Thevenin equivalent impedances (in Ohms) in intact system at the G376 point of interconnection without contribution from G376.

Pos Seq.	Neg. Seq.	Zero Seq.
2.88 + j 11.4 Ω	2.88 + j 11.4 Ω	6.93 + j 24.7 Ω

Table B.3 – Thevenin equivalent impedances (in Ohms) measured at the G376 point of interconnection without the contribution from G376 and also with the G376 – North Fond du Lac 138kV Line out of service.

Pos Seq.	Neg. Seq.	Zero Seq.
5.67 + j 20.97	5.67 + j 20.97	10.62 + j 40.30

Appendix C

Power Flow Analysis

Table C.1 – Summer 2006 Thermal Overloads Identified. 160 MW Generation Delivery from G376 to NSP(25%) and ComEd (75%)

Limiting Element	Existing MVA Rating	Worst Contingency	MVA Flow without G376	MVA Flow with G376	Solution for Limiting Element
		Base case			
		There were no base case violations			
		Single Contingencies			
Wautoma 69/138 kV Transformer	46.7	Wautoma – Sand Lake 138 kV	47.0	58.5	Yes ¹
		Additional overloads due to Double Contingencies			
Y-27 Metomen – Rosendale 69 kV	36	N. Fond du Lac – Metomen 138 kV Green Lake – G376 138 kV	37.8	43.7	No ²

Note:

1 – Required upgrades have been identified as part of the ISIS.

2 – There is no previously identified project by ATC to solve the loading problem. Operating restrictions will be used to mitigate the impact on the overloaded element. ATC is still reviewing the line rating. However, the most limiting component is the line conductor operating temperature due to clearances.

Table C.2 – Winter 2006/2007 Thermal Overloads Identified. 160 MW Generation Delivery from G376 to NSP(25%) and ComEd (75%)

Limiting Element	Existing MVA Rating	Worst Contingency	MVA Flow without G376	MVA Flow with G376	Solution for Limiting Element
		Base case			
		There were no base case violations			
		Single Contingencies			
		There were no single contingency violations			
		Additional overloads due to Double Contingencies			
		There were no double contingency violations			

Table C.3 – Identified under-voltage violations for Winter 2006/2007. 160 MW Generation Delivery from G376 to NSP(25%) and ComEd (75%). Power factor of 0.95 leading (absorbing VARs)

Worst Contingency	Bus with Violation Voltage	Bus Voltage without G376	Bus Voltage with G376	Solution for Voltage Violation
796L41 Edgewater – Cedarsauk 345 kV	Auburn 138 kV	0.892	0.881	Yes *

* Previously identified capacitor bank projects (at G368 138 kV bus, Hartford 138 kV bus and Burlington 138 kV bus) expected to be in service before G376 service date will mitigate this under voltage violations.

Table C.4 – Identified under-voltage violations for Summer 2006. 160 MW Generation Delivery from G376 to NSP(25%) and ComEd (75%). Power factor of 0.98 leading (absorbing VARs)

Worst Contingency	Bus with Violation Voltage	Bus Voltage without G376	Bus Voltage with G376	Solution for Voltage Violation
G376 - North Fond du Lac 138 kV	Roeder 138 kV	0.911	0.896	Yes *
	Wautoma 138 kV	0.908	0.890	

* Operating G376 at 0.99 power factor leading (absorbing) mitigates the identified under-voltage violation.

Appendix D

Summary of Operation Restrictions

Table D.1 – Identified Operation Restrictions on the G376 Generation Under Prior Outage Scenarios

Prior Outage¹	G376 Max Allowable Output (MW)	Worst Next Contingency	Limiting Element²	MVA Rating	Reason	Season
N. Fond du Lac – Metomen 138 kV	0	Green Lake – G376 138 kV	Metomen – Rosendale 69 kV	36	Thermal	Summer
Green Lake – G376 138 kV	0	N. Fond du Lac – Metomen 138 kV	Metomen – Rosendale 69 kV	36	Thermal	Summer
Green Lake – Roeder 138 kV	80 MW	Green Lake – North Fond du Lac 138 kV	G376 trips due to over-voltage	N/A	Stability	Year Round
Green Lake – N. Randolph 138 kV	80 MW	Green Lake – North Fond du Lac 138 kV	Unable to find a stable operating point	N/A	Stability	Year Round
Green Lake – N. Fond du Lac	80 MW	Green Lake – Roeder 138 kV	G376 trips due to over- voltage	N/A	Stability	Year Round

Table D.2 – Outage Statistics for Contingent/Prior Outage Lines Identified Under Prior Outage Scenarios

Contingent Element	Line Length (miles)	Total # of Outages 1/1/2000 – 1/1/2005	Average Duration (minutes)	Outages per 100 mile-years
X-3: North Fond du Lac – Metomen 138 kV ¹	42.53	1	0.08	0.55
X-4: Green Lake – North Fond du Lac 138 kV	29.30	4	2.83	2.73
X-10: Green Lake – Roeder 138 kV ²	25.88	3	19.06	2.32
X-30: Green Lake – North Randolph 138 kV	13.23	6	81.45	9.07

Note:

1 – Line length for North Fond du Lac – Metomen 138 kV is measured from North Fond du Lac to North Randolph 138 kV, the next breakered substation.

2 - Line length for Green Lake – Roeder 138 kV is measured from Green Lake to Wautoma 138 kV, the next breakered substation.

Appendix E

Proposed Fault Ride-Through Characteristics For G376 Wind Turbines

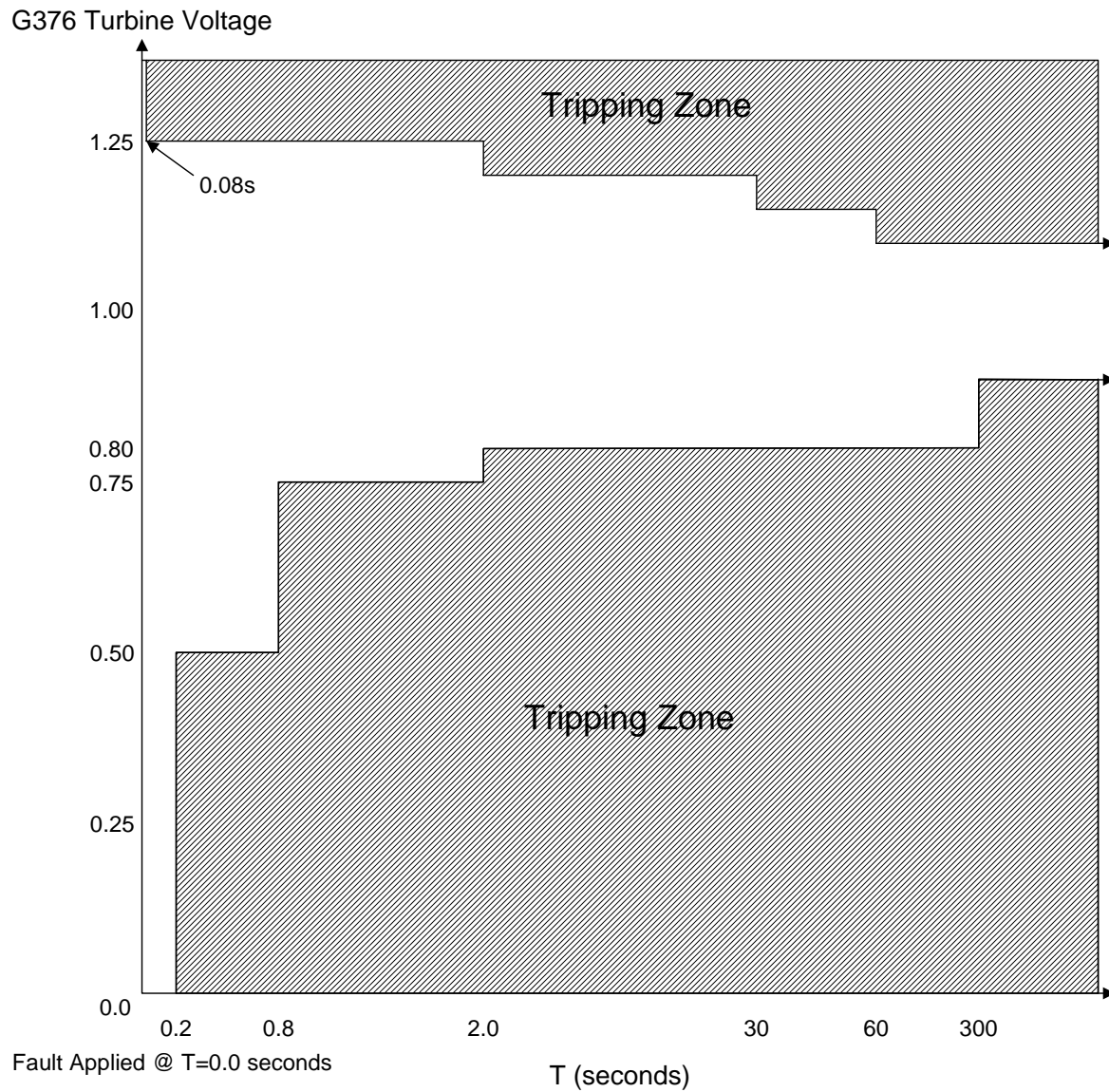


Figure E.1 – Proposed Fault Ride-Through Characteristics Related to Voltage Tripping of G376 Wind Turbines

Appendix F

Study Criteria

Study Criteria

F.1 Contingencies

For stability analysis, a set of branches in the vicinity of the generator/power plant of concern is selected as contingencies, based on engineering judgment. Fault analysis is performed for the following three categories of contingency conditions:

1. Fault cleared in primary time with an otherwise intact system.
2. Fault cleared in delayed clearing time (i.e. breaker failure conditions) with an otherwise intact system.
3. Fault cleared in primary clearing time with a pre-existing outage of any other transmission element.

For power flow analysis, contingencies include:

1. N-1 contingencies: All lines and transformers operated at 69kV and above in Wisconsin Power & Light Co. (Alliant Energy – East), Wisconsin Electric Power Co., Wisconsin Public Service Corp., Madison Gas & Electric Co., Upper Peninsula Power Co. control areas; All line and transformers operated at 345 kV and above in the Commonwealth Edison, Northern States Power, Alliant West and Minnesota Power control areas; All line and transformers operated at 161 kV and above in the Dairyland Power Cooperative control area.
2. Selected N-2 and multiple contingencies that ATC has determined to be significant.

F.2 Monitored Elements

F.2.1 Intact System, N-1 and Special Multiple Contingency Evaluation Using ACCC

All load carrying elements operated at 69kV and above in the following control areas/zones were studied: Wisconsin Power & Light Co. (Alliant Energy – East), Wisconsin Electric Power Co., Wisconsin Public Service Corp., Madison Gas & Electric Co., Upper Peninsula Power Co., Commonwealth Edison, Northern States Power, and Dairyland Power Cooperative Control Areas.

F.2.2 N-2 Contingency Evaluation Using Linear Transfer Analysis Method

All load carrying elements operated at 69kV and above in the following control areas/zones were monitored in this study: Wisconsin Power & Light Co. (Alliant Energy – East), Wisconsin Electric Power Co., Wisconsin Public Service Corp., Madison Gas & Electric Co., Upper Peninsula Power Co., Commonwealth Edison, Northern States Power and Dairyland Power Cooperative.

F.3 Thermal Loading Criteria

F.3.1 Intact System, N-1 and Special Multiple Contingency Evaluation Using ACCC

Under intact system conditions, the loading of all transmission elements with distribution factors greater than 0.05 per unit must not exceed the applicable normal rating (Rate A). Under contingency conditions, the loading of all transmission system elements with distribution factors greater than 0.03 per unit must not exceed the applicable emergency rating (Rate B).

F.3.2 N-2 Contingency Evaluation Using Linear Transfer Analysis Method

Under N-2 contingency conditions, the loading of all transmission system elements with distribution factors greater than 0.03 per unit must not exceed 100% of the applicable emergency rating.

F.4 Steady State Under Voltage Criteria

F.4.1 Intact System, N-1 and Special Multiple Contingency Evaluation Using ACCC

Under intact system conditions, the voltage magnitude of all transmission system buses with a decrease of 0.01 per unit due to the Generator must not be lower than 0.95 per unit. Under contingency conditions, the voltage magnitude of all transmission system buses with a decrease of 0.01 per unit due to the Generator must not be lower than 0.90 per unit.

F.4.2 N-2 Contingency Evaluation

Voltage violations were not evaluated for N-2 contingencies.

F.5 Stability Criteria

Critical Clearing Time (CCT) is a period relative to the start of a fault, within which all generators in the system remain stable (synchronized). CCT is obtained from simulation. Maximum Expected Clearing Time (MECT) determines a period of time that is needed to clear a fault using the existing system facilities. MECT is dictated by the existing system facilities. In any contingency, if the computed CCT is less than the MECT plus a margin determined by ATC (1.0 cycle in this study), it is considered an unstable situation and is unacceptable. Otherwise, it is considered acceptable stability performance.

In the context of stability analysis, voltages of all transmission system buses must recover to be at least 70% of the nominal system voltages immediately after fault removal and 80% of the nominal system voltages in 0.5 second after fault removal.